

The Optimizing Control and Energy Saving Operations of One Teaching Building

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Abstract: The control system of the central air conditioning in one teaching building is optimized in this paper, which includes the rational controls of a water chilling unit's available machine time and down-time in advance, the operational numbers of the units and pumps, the temperature of the chilled water, and so on. By means of the experiments that the units ran in summer, the results reveal that compared with traditional air conditioning system that does not adopt the automatic control system, it can save the energy consumption of the air conditioning system to a large extent. In other words, the optimizing control system possesses enormous development potential. Therefore, the control method and the energy-saving strategies in this paper can provide information and references for other central air conditioning systems to save energy.

Key words: cold source; energy-saving operation; number control; water temperature control

1. FOREWORD

With the fast development of economy and technology, it becomes more and more popular for the public buildings to adopt the central air conditioning systems. This phenomenon causes the sharp increase of the energy consumption on air conditioning systems, which accounts for 50% of the total energy consumption of buildings^[1]. In addition, the energy consumption of the cold source system and the water system cost 70% of the total air conditioning energy consumption. That is to say, it can not only reduce the labor intensity and satisfy the indoor comfort but also save the energy consumption

of the air conditioning systems to a large extent as long as the cold source system and the water system are properly optimized. The optimized cold source systems in one teaching building are exemplified in this paper.

2. INTRODUCTION OF THIS PROJECT

The teaching building is a multifunctional building which is composed of offices, classrooms, laboratories and assembly rooms. The whole covered area is 70032 square meters, and the building is of 99.1 meters high. It consists of 3 floors under ground that is used to place equipments and 26 floors up ground. Moreover, from first to sixth floor are used for teaching, and from seventh to twenty-sixth floor are used for office and meeting. The total area for air conditioning is 37042 square meters. Automatic systems are adopted to this building which can supervise the air conditioning system, water supply and sewerage system, distribution system and illumination system.

7300kW cooling load should be supplied to meet the indoor comfort after calculation. In order to assure that the water chilling units can run in high efficiency when the load is low, a screw water chilling unit are equipped in this building. In addition, the primary pump system is used, and the supply of the cold source is changeless, and the supply of the load is variable. The one-to-one correspondence for the unit and the pump is adopted in the air conditioning system. The specific parameters of cold source and accessories section are shown on table 1.

Tab.1 Cold source and the accessories section

Serial number	Name	Parameter	Unit	Number
1	Centrifugal water chilling unit	$Q=2637\text{kW}$ $N=490\text{kW}$ Input and output water temperature 6/13℃	Dais	3
2	Screw water chilling unit	$Q=1167\text{kW}$ $N=251\text{kW}$ Input and output water temperature 6/13℃	Dais	1
3	Chilling pump	$G=324\text{m}^3/\text{h}$ $H=37\text{m}$ $N=45\text{kW}$	Dais	3 in use one stand-by
4	Chilling pump	$G=128\text{m}^3/\text{h}$ $H=37\text{m}$ $N=18.5\text{kW}$	Dais	1 in use one stand-by
5	Cooling pump	$G=700\text{m}^3/\text{h}$ $H=32\text{m}$ $N=75\text{kW}$	Dais	3 in use one stand-by
6	Cooling pump	$G=350\text{m}^3/\text{h}$ $H=32\text{m}$ $N=55\text{kW}$	Dais	1 in use one stand-by
7	Cooling tower	$G=700\text{m}^3/\text{h}$ $N=22\text{kW}$	Dais	3
8	Cooling tower	$G=350\text{m}^3/\text{h}$ $N=11\text{kW}$	Dais	1

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3. CONTROL OF THE COLD SOURCE SYSTEM

The control of the cold source system can be summarized into three points: Firstly, the run time should be accumulated, then the unit that costs shortest time can be selected automatically by means of length of the run time; Secondly, the on-off time in advance of the water chilling unit should be confirmed properly; Thirdly, the number of units in service and the outlet water temperature of the water chilling unit should be ensured on the foundation of the outdoor air temperature, humidity and service condition in the air conditioning rooms. This paper pays more attention to the second and the third points.

4. DETERMINATION OF THE ON-OFF TIME IN ADVANCE

4.1 Determination of the off Time in Advance

The maintenance structure and the chilled water have the ability of accumulating certain cooling energy, so the water chilling units can be stopped beforehand, and the chilling pump should keep on operating. This way can decrease the air conditioning energy consumption to a large degree on the condition of meeting the indoor comfort.

The setting air temperature is 26℃ of the indoor air conditioning rooms in summer. After simulation in different typical rooms, it is found that the air temperature fluctuates around 28℃, and the variable is about 2℃ on the condition that the water chilling units stop half an hour ahead of off duty, but the chilling pump keeps on operating. Thus, the indoor air temperature will increase a few degrees. This way is in favor of the workers to adapt to the outdoor environment after they are off duty and leave the air conditioning environment.

4.2 Settlement of the Available Unit Time in Advance

The temperature of the chilled water rises between 18℃ and 23℃ during a night. The water chilling unit has to be operating for 2 to 3 hours in the first instance so as to meet the setting temperature. When the water chilling unit is running in the beginning, it can only supply few cooling energy and need a relative long time to lower the temperature. The chilled water

temperature should be declined before work so that the air temperature in the air conditioning rooms can be decreased in a short time to the setting temperature, which can build a moderate indoor environment for the students and teachers.

4.2.1 Problems and Settlements of Starting Up Beforehand

1) Problems

The electric hydrovalves and the ending fans are concatenated, that is, the hydrovalve are closed when the end equipments are off. Although the water chilling unit is started, the chilled water system can not be circulated. A chilled water return circuit is formed between the water chilling unit and the by-pass tube. In addition, the water filled in return circuit is small so that it can be chilled in a short time. However, the great mass of the water in the chilled water line is still in a relative higher temperature situation. Thus, the problem is that the precooling effect can not be achieved.

2) Settlement

The method of opening the electric hydrovalves of all the air handling units is suggested when precooling. It can form a chilled water return circuit quickly. The temperature of the chilled water in the supply lines and the return lines of the fan coil units is still high after the precooling process is finished. However, the mixed chilled water temperature will not be affected too much for the water in the fan coil units only occupied 16% of the total chilled water capacity.

3) Energy saving method in operation

The low temperature chilled water in the by-pass tube mixed with the relative higher temperature water in the total return line can not only reduce the inlet water temperature of the water chilling unit, but also reduce the outlet water temperature of the unit. That means the efficiency of the water chilling unit is decreased on the condition of the same refrigerating output. The decrease of the back water temperature can also induce to cost much more time to precooling.

Although it doesn't mean too much change of the efficiency under different loads, the opening time of the chilling pump, cooling pump and the chilled tower will indeed last longer. So the precooling energy consumption will increase if there is water flows in the by-pass tube. The value of the pressure difference by-pass valve is set by means of the pressure difference when all of the air conditioning terminals are opened. Part (2) describes that all of the electric hydrovalves of the fan coil units are closed when the chilled water system is precooling. Opening the electric hydrovalves merely will cause the pressure difference between the water knockout vessel and the water collect vessel to overpass the setting value, which will results in the opening of the pressure difference by-pass valve. Therefore, there is flowing water in the by-pass line all the time when the system is precooling.

No water is allowed to flow though the by-pass tube on the target of reducing the precooling energy consumption. In the practical operation, the pressure difference by-pass valve can be forced to close by the central control room. The work state point of the chilling pump will keep stable though the pressure difference by-pass valve is closed, because the dynamic flux balanced valve is installed in each unit which can guarantees the water flux fluctuating between 95% and 105 % of the normal value^[2]. The whole system will operate safely and energy-saving.

4.2.2 Determination of the Available Machine Time and Available Machine Number Ahead of Schedule

The water capacity of the chilled water system is 58.6m³ and the initial temperature of the chilled water before starting up is between 18℃ and 23℃. The precooling time and the precooling energy consumption when different numbers of units are running can be got by mean of the performance curve of the units. The results are shown on table 2.

Start the centrifugal unit will cost the least energy to precool, because the efficiency of

centrifugal unit is higher than the screw unit when it is running in high load. The increasing number of the operating centrifugal units will decrease the precooling time to some degree. However, this way can not reduce the power consumption. In the morning, the load is low relative to other times, so it is enough of starting one centrifugal unit to meet the cooling load. In addition, the advance operating time is about 21minutes to 33minutes which will be determined by the initial temperature of the chilled water.

Tab.2 The precooling time and the precooling energy consumption

Combination of units in service	Time (minute)	Power consumption (kWh)
One screw unit	50~74	238~345
One centrifugal unit	21~33	196~290
One screw unit plus one centrifugal unit	15~23	209~307
Two centrifugal units	10~16	196~290

5. NUMBER CONTROL OF THE WATER CHILLING UNITS

The cold source system consists of three centrifugal units and one screw unit. There are different combinations of the units to satisfy the same load. However, each combination cost different energy, that is, there must be one optimal combination so that the energy consumption will cost least. The optimal combination can be got on the base of the performance curves of the screw unit and the centrifugal unit. The results are shown on table 3.

Tab.3 The optimal combination under different loads

Load (kW)	Combination of the running units
$Q \leq 1167$	One screw unit
$1167 < Q \leq 2637$	One centrifugal unit
$2637 < Q \leq 5274$	Two centrifugal units
$5274 < Q$	Three centrifugal units

Note: the results is got on the condition of running at the nominal parameters

The exchanging ability of the heat exchanger

will reduce along with the time increase, and the unit's refrigerating output will not meet the normal refrigerating output, which will result in the change of the performance curve. In addition, the normal performance parameter should be amended by the practical performance parameter. In the practical operation, the operating number also should take the measured value of the outlet water temperature into account. When the measured value of the outlet temperature is higher than the unit's setting value for a long time, another unit should be added. The added unit can be determined in terms of table 3.

6. OUTLET CHILLED WATER TEMPERATURE CONTROL OF THE WATER CHILLING UNITS^[3]

The air conditioning load is altering along with the outside climate. The cooling load in summer of the teaching building is simulated in this paper, and the results are shown on table 4.

Tab.4 The hour percentage of different cooling load

Load percentage (%)	<20	20~50	50~70
Time percentage (%)	29	39.3	22
Load percentage (%)	70~80	80~90	>90
Time percentage (%)	6.6	2.3	0.8

From table 4, we can see that the run time under 70% of the total cooling load accounts for 90% of the whole run time, and the run time in full load only accounts for 1%. That is to say, there is no need to maintain a constant water temperature at all of the refrigerating time. The COP value can rise if only increasing the outlet water temperature of the unit, thus, the setting temperature can be altered flexibly by means of the changing loads. In this way, the operating efficiency of the units can be improved and the operating consumption can be decreased.

6.1 The Chilled Water Temperature's Influence on the Heat Transfer Capability of the Air Conditioning Terminals

6.1.1 The Chilled Water Temperature's Influence

on the Heat Transfer Capability of the Fan Coils

According to the reference ^[4], when the number of running units is decreased on operation at part load, the water passing through the fan coils will not be under nominal water flux and the cooling load that fan coils can supply will be above the nominal refrigerating output. Although the increase of the water temperature will result in the decrease of the refrigerating output, the indoor temperature and humidity can be maintained in a comfort scale if only the setting value of the chilled water lowers than 12℃^[5]. In other words, the chilled water temperature's influence on the heat transfer capability is not too much. Therefore, this paper concerns more about the chilled water temperature's influence on the heat transfer capability of the air conditioning units.

6.1.2 The chilled water temperature's influence on the heat transfer capability of the air handling units
Different inlet temperature of chilled water and the variable refrigerating output curve can be got by means of the heat exchange regularity of the surface coolers (shown in Fig1). The heat transfer quantity is decreasing along with the increasing inlet water temperature. When the inlet water temperature is 12℃, relative refrigerating output accounts for 60% of the setting output.

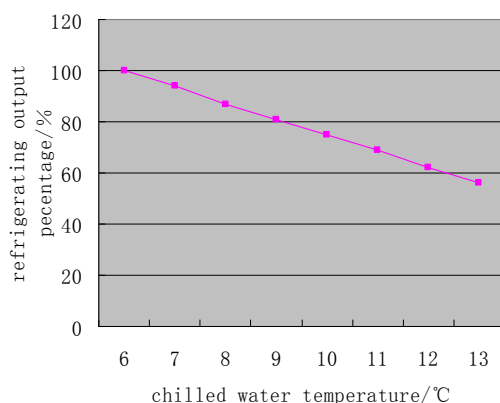


Fig.1 The chilled water temperature's influence on the refrigerating output

Note: The data are calculated on the condition that the refrigerating output is 100% when the supply-water temperature is 6℃

In the practical operation, the number of

running units is changing along with the variable air conditioning loads, which causes the change of the water flux. Thus, both chilled water temperature and the water flux are adjusted when the system is operating at part load. The relative refrigerating output of the units under different chilled water temperature and water flux is shown on Fig2.

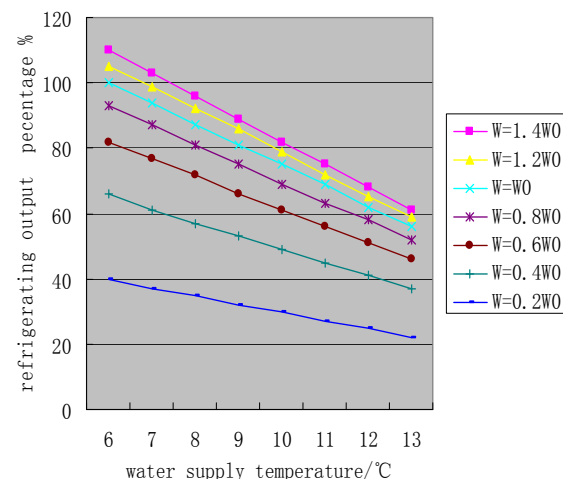


Fig.2 The chilled water temperature and the water flux influence on the refrigerating output

Note: The data are calculated on the condition that the refrigerating output is 100% when the supply-water temperature is 6℃ and the water flux is W_0

6.2 Control Scheme of the Outlet Chilled Water Temperature

The fourth paragraph shows that the combination of the start-stop units and the water flux in the chilled water systems can be confirmed under different loads. On the base of chilled water flux and temperature's influence on the refrigerating output (shown on Fig2), the setting temperature of the outlet chilled water in different cooling load can be attained after calculation. When the outlet temperature is lower than 12℃, the desiccation ability drops sharply. The temperature should be designed under 12℃ for the sake of ensuring the indoor comfort.

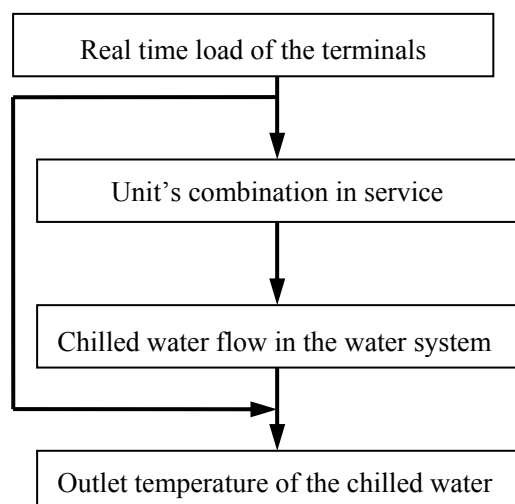


Fig.3 Control process of the outlet chilled water temperature

Take some correction factors into account, such as the heat-transfer coefficient of the cooler decreasing and the fresh air inlet condition changing. The control strategy of the outlet chilled water temperature is shown on table 5.

Table 4 and table 5 depict that when the chilled water temperature is 6℃, it only accounts for 2% of the whole air conditioning time, and when the setting water temperature is 9℃, it accounts for 82% of the whole time. Therefore, the energy consumption of the water chilling units can be reduced taking the method of altering the temperature of the chilled water in summer.

Tab.5 Setting temperature of the chilled water outlet in different load

load (kW)	Setting temperature (℃)
$Q \leq 3654$	10
$3654 \text{ kW} < Q \leq 4384$	9
$4384 \text{ kW} < Q \leq 5274$	8
$5274 \text{ kW} < Q \leq 6210$	7
$6210 \text{ kW} < Q$	6

7. CONCLUSIONS

The energy consumption of the cold source system and the water systems takes a great part of

the total air conditioning energy consumption, thus, it is of great importance to operate the chilled water system efficiently. The chilled water system in one teaching building is exemplified to illustrate the optimizing strategy of the chilled water system in this paper. Firstly, determination of the start-stop time of the unit in advance; secondly, the determination of the outlet water temperature and the combination of the units in service on the base of different air conditioning loads. The control methods above can also provide a reference for other cold source systems on energy saving.

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